

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

PSOFC/GT Hybrid Power Systems Demo Status & Development Issues

Presented at Turbine Power Systems Conference
Galveston, Texas
February 26, 2002

James A. Ciesar
Stationary Fuel Cells
Siemens Westinghouse Power Corporation
1310 Beulah Rd
Pittsburgh, PA 15235
412-256-2564
james.ciesar@siemens.com

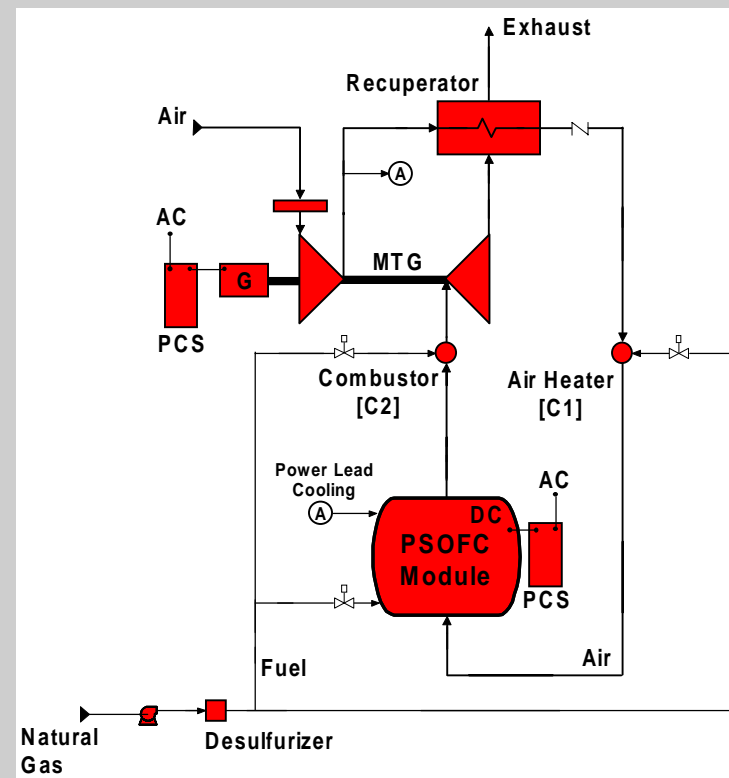
Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

- Benefits of PSOFC/GT Hybrids
- Status of Demonstrations
- Future Development Plans
- Development Issues
 - Component Matching
 - SOFC Stack
 - MTG
 - System Integration Issues

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

PSOFC/GT Cycle

- MTG compressor pressurizes SOFC module
- SOFC power output enhanced by pressure
- SOFC “fires” MTG
- Combustor (C2) and air heater (C1) used only for startup
- Employs heat recuperator



Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

Benefits of PSOFC/GT Hybrid Power Systems

- SOFC exhaust heat converted to electricity
- Highest electrical efficiency
 - rivaling that of CC central generation at 1/1000 scale
 - 56-60% near term
 - >70% far term
- Cell power output enhanced
- Lowest emissions
 - All fuel reacted in SOFC at ~1000 °C
 - NO_x < 1 ppmv
 - SO_x < 0.1 ppmv
 - CO₂ < 370 lb/MWh

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

220 kWe PSOFC/GT Hybrid Proof of Concept Demonstration

- World's first working PSOFC/GT hybrid
- Built for Southern California Edison
- Located at and operated by University of California - Irvine NFCRC



Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

220 kWe PSOFC/GT Hybrid Demonstration

- 1152 cell SOFC stack
- IRES PowerWorks MTG
 - nominally 70 kWe
 - in hybrid application operates at 720 °C* and ~2.8 pressure ratio
 - *some air bypasses SOFC
- Tested at for over 1000 hours
 - up to 186 kWe AC equiv*
 - up to 52% equiv AC eff.*
- *Not grid connected

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

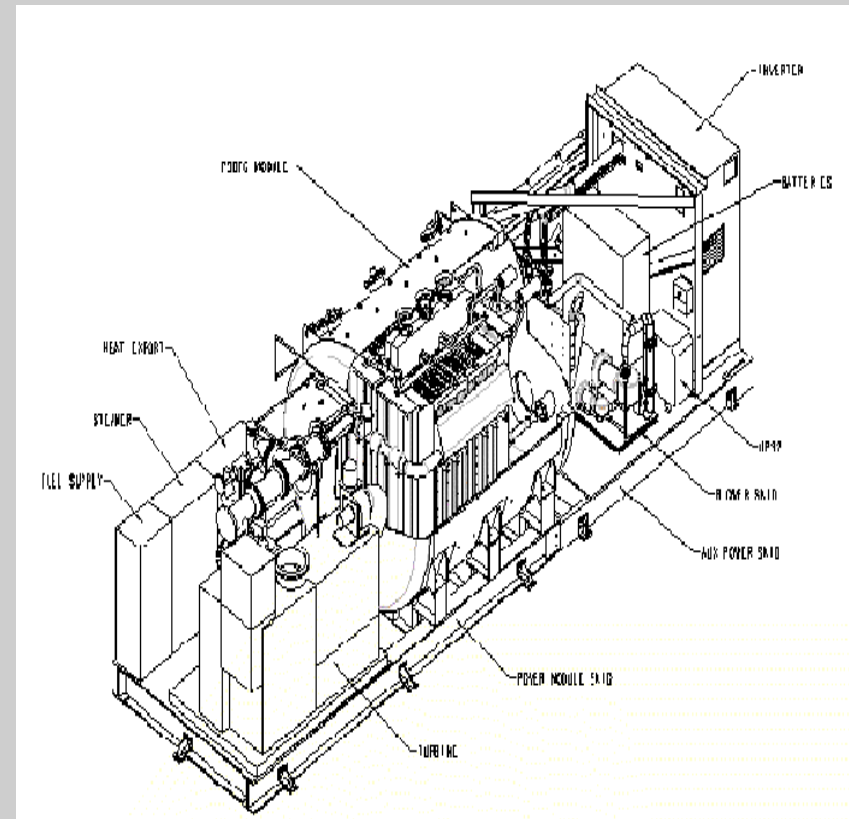
220 kWe PSOFC/GT Hybrid Demonstration

- Demonstrated PSOFC and MTG integration and operation
- Demonstrated safe, unattended operation and shutdown
- $\text{NO}_x < 1 \text{ ppmv}$

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

300 kWe PSOFC/GT Proof of Concept Hybrid Demonstrations

- RWE Energie, Essen
Germany
 - September 2002
- Edison S.p.A., Italy
 - January 2003



Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

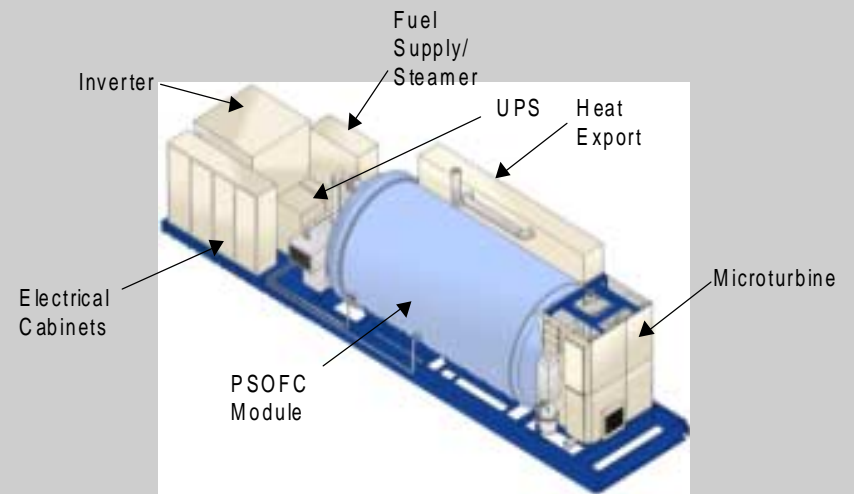
300 kWe PSOFC/GT Demonstrations

- 1704 cell SOFC stack
- European turbine manufacturer
 - nominally 100 kWe @ 0.79 kg/sec, 950 °C TIT
 - in hybrid application produces ~57 kWe @ 800 °C TIT, 0.64 kg/sec, 3.8 PR
- 300 kWe electrical output
- 56% AC eff.
- 140 kWt heat output

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

Planned 550 kWe PSOFC/GT Development

- Largest truck-transportable, factory assembled PSOFC/GT
- Commercially attractive power rating
- Demonstration site under negotiation



Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

Planned 550 kWe PSOFC/GT Development - Preliminary Design

- 3456 cell SOFC stack
- MTG sized for 840 °C TIT, 1.2 kg/sec airflow, 3.5 Pr
- 550 kWe AC output @ ~57% eff.
- 175 kWt thermal output
- >80% total eff.
- NOx emissions <1 ppm
- SOx, VHC emissions <0.1 ppm

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

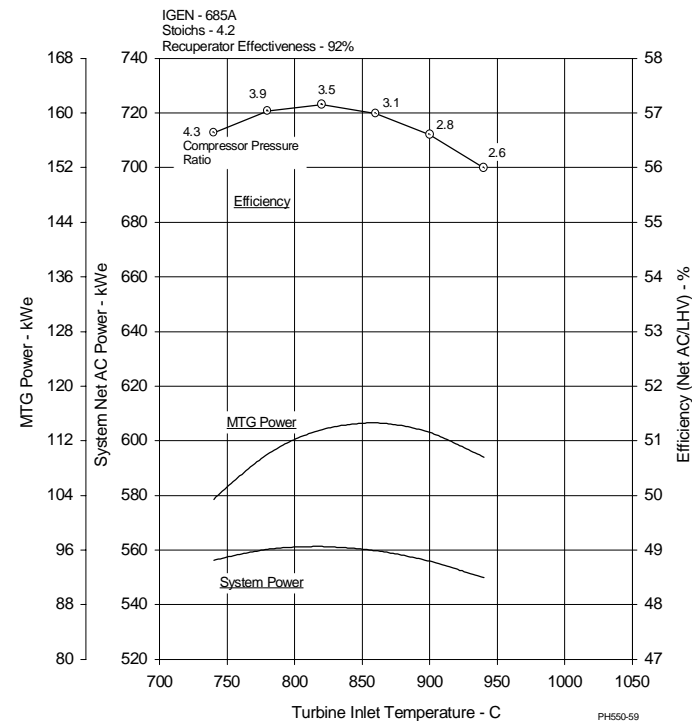
550 kWe Development Issues

- Component Matching
- SOFC Power Module
- MTG
- System Integration Issues

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

Component Matching

- Narrow temp window for MTG
- Limited expansion ratio
- Competing effects of flow rate variations within:
 - SOFC stack
 - recuperator
 - MTG



Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

SOFC Power Module Issues

- Optimize stack size and design
- Maximize utilization of existing components from soon to be commercial CHP250
- Design of pressure vessel
- Maximize utilization of existing BOP sub-systems
- Recuperator design
- Rapidly adopt basic cell technology innovations
 - SECA
 - wider temperature range SOFC

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

MTG Issues

- Selection of “standard” MTG as base
- Verify/optimize aerodynamics for design TIT, PR, flow rate
- Accommodate air extraction at compressor, reentry at power turbine
- Thorough surge mapping
- Modifications to control logic and systems
- Custom combustor and air preheater (used only for startup)
- Tradeoffs with recuperator and heat export system

Pressurized Solid Oxide Fuel Cell/Gas Turbine Hybrid Power Systems

System Integration Issues

- Controllability and stability
- Protection against pressure transients in planned and emergency stops
- Prevent airflow reversals
- High volume of pressurized gas, high thermal inertia, long shutdowns
- Design for unattended operation
- Safety analysis, FMEA